CLAIMS

What we claim is:

5 1. A method of depositing a heteroepitaxial single-crystal film on a plurality of step-free surfaces of a basal plane surface orientation of a selected single-crystal substrate material serving as a wafer, said method comprising the steps of:

(a) preparing more than one step-free planar surface on the selected substrate, wherein each of said plurality of step-free surfaces has a boundary of selected size
10 and shape;

(b) selecting a heteroepitaxial film material whose chemical bonding structure is tetrahedral and exhibits a property that under predetermined growth conditions that growth of said heteroepitaxial film material grows in bilayers on said selected step-free planar surface;

15 (c) carrying out a selected deposition process under selected growth conditions that produce (1) a single nucleus of said heteroepitaxial film material at least one bilayer thick on said step-free surface with said selected boundary, followed by (2) lateral expansion of said single nucleus over entire surface defined by said selected boundary of said plurality of step-free basal plane surfaces before a
20 second nucleus can form elsewhere on the said selected step-free planar surface, and (3) a single nucleus of the second bilayer of heteroepitaxial film material on top of the said first bilayer of heteroepitaxial film followed by (4) lateral expansion of the single nucleus over the entire surface defined by the selected boundary of the step-free basal plane surface before a second nucleus can form

elsewhere on the first bilayer of heteroepitaxial film on the selected step-free

planar surface; and

(d) providing growth of subsequent additional bilayers of the said heteroepitaxial

film by providing a suitable set of growth conditions until a desired thickness of

5   said heteroepitaxial film is achieved.

2.   The method according to claim 1, wherein the said selected deposition process of

step (c) comprises carrying out deposition under selected growth conditions over a

selected period of time to produce an average rate of nucleation (NR1) and an average

10   velocity of lateral island expansion (VLE1) for the growth of the first heteroepitaxial

bilayer and an average rate of nucleation (NR2) and an average velocity of lateral

expansion (VLE2) for the growth of the second heteroepitaxial bilayer, wherein:

(a) said growth conditions and said step-free

planar surface size and shape are selected such that said average velocity of

15   lateral island expansion (VLE1) divided by the said average rate of

nucleation (NR1) for the first bilayer and said average velocity of lateral

island expansion (VLE2) divided by the said average rate of nucleation

(NR2) for the second bilayer are both less than the product of a planar area

(A) of the said step-free planar surface multiplied by the longest planar

20   accumulated length dimension (L_A) of the said selected step-free planar

surface; and

(b) said selected period of time is greater than the sum of the following:

70

(i)   the mathematical inverse of the product of the planar area (A) of said selected step-free planar surface multiplied by said average rate of nucleation (NR1) with the result thereof being termed T2D1;

5   (ii)   the quotient of the said longest planar accumulated length dimension (L_A) of the said selected step-free planar surface divided by said average velocity of lateral island expansion (VLE1) with the result thereof being termed TC1;

(iii)   the mathematical inverse of the product of the planar area (A) of

10   said selected step-free planar surface multiplied by said average rate of nucleation (NR2) with the result thereof being termed T2D2; and

(iv)   the quotient of the said longest planar accumulated length dimension (L_A) of the said selected step-free planar surface divided

15   by said average velocity of lateral island expansion (VLE2) with the result thereof being termed TC2.

3.   The method according to claim 2, wherein said growth conditions comprise a set of growth parameters comprising at least substrate temperature, reactor pressure used for

20   said deposition, concentration of reactor precursors for material being deposited, composition of carrier gas used within said reactor, and flow rate of carrier gas within said reactor.

7. The method according to claim 1, wherein step (c) comprises multiple selected growth conditions carried out in a sequential manner.

8. The method according to claim 7, wherein said plurality of step-free surfaces on the selected substrate comprise at least two different planar areas defined by said boundary selections.

12. The method according to claim 7, wherein said multiple selected growth conditions are selected so as to sequentially increase the average nucleation rate of each said growth condition carried out in said sequential manner.

9. The method according to claim 8, wherein said selected growth conditions are selected so as to sequentially increase the average nucleation rate of each said growth condition carried out in said sequential manner.

13. The method according to claim 12, wherein said sequential increases of said average nucleation rate is accomplished in a staircase manner.

10. The method according to claim 9, wherein said sequential increases of said average nucleation rate is accomplished in a staircase manner.

14. The method according to claim 12, wherein said sequential increase of said average nucleation rate is accomplished in a ramp manner.

72

11. The method according to claim 9, wherein said sequential increase of said average nucleation rate is accomplished in a ramp manner.

12. The method according to claim 1, wherein said single-crystal substrate material has a hexagonal crystal structure and is selected from the group consisting of 6H-SiC and 4H-SiC.

13. The method according to claim 1, wherein said single-crystal substrate material has a rhombohedral crystal structure and is 15R-SiC.

14. The method according to claim 1, wherein said single-crystal substrate material has a cubic crystal structure and is selected from the group consisting of silicon, germanium, SiGe, GaAs, and GaP.

15. The method according to claim 12, wherein said heteroepitaxial single-crystal film has a hexagonal crystal structure and is selected of a material different from the substrate and said different material is selected from the group consisting of 2H-SiC; 2H-GaN; 2H-AlN; 2H-AlGaN; and 2H-InGaN.

16. The method according to claim 13, wherein said heteroepitaxial single-crystal film has a hexagonal crystal structure and is selected of a material different from the substrate material and said different material is selected from the group consisting of 2H-SiC; 2H-GaN; 2H-AlN; 2H-AlGaN; and 2H-InGaN.

32

17. The method according to claim 14, wherein said heteroepitaxial single-crystal film has a hexagonal crystal structure and is selected of a material different from the substrate material and said different material is selected from the group consisting of 2H-

5   SiC; 2H-GaN; 2H-AlN; 2H-AlGaN; and 2H-InGaN.

22

18. The method according to claim 12, wherein said heteroepitaxial single-crystal film has a cubic crystal structure and is selected of a material different from the substrate material and is further selected from the group consisting of silicon, germanium, SiGe,

10   diamond, 3C-SiC, GaAs, AlAs, AlGaAs, InAs, InP, InGaAs, InP, InGaAsP, cubic-GaN, cubic-AlN, cubic-AlGaN, cubic-InGaN.

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19. The method according to claim 13, wherein said heteroepitaxial single-crystal film has a cubic crystal structure and is selected of a material different from the substrate

15   material and is further selected from the group consisting of silicon, germanium, SiGe, diamond, 3C-SiC, GaAs, AlAs, AlGaAs, InAs, InP, InGaAs, InP, InGaAsP, cubic-GaN, cubic-AlN, cubic-AlGaN, cubic-InGaN.

33

20. The method according to claim 14, wherein said heteroepitaxial single-crystal

20   film has a cubic crystal structure and is selected of a material different from the substrate material and is further selected from the group consisting of silicon, germanium, SiGe, diamond, 3C-SiC, GaAs, AlAs, AlGaAs, InAs, InP, InGaAs, InP, InGaAsP, cubic-GaN, cubic-AlN, cubic-AlGaN, cubic-InGaN.

75

34
21.   The method according to claim 1, wherein said selected substrate material is
hexagonal-SiC and said heteroepitaxial film material is 3C-SiC.

5   22.   The method according to claim 2, wherein said selected substrate material is
hexagonal-SiC and said heteroepitaxial film material is 3C-SiC.

23.   The method according to claim 6, wherein said selected substrate material is
hexagonal-SiC and said heteroepitaxial film material is 3C-SiC.

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24.   The method according to claim 18, wherein said selected substrate material is
hexagonal-SiC and said heteroepitaxial film material is 3C-SiC.

25.   The method according to claim 6, wherein said multiple growth conditions have

15   an initial growth temperature for an initial selected growth condition and said initial
growth temperature is reduced during said sequence until a final growth temperature is
reached corresponding to a final selected growth condition.

26.   The method according to claim 24, wherein said multiple growth conditions have

20   an initial growth temperature for an initial selected growth condition and said initial
growth temperature is reduced during said sequence until a final growth temperature is
reached corresponding to a final selected growth condition.

27. The method according to claim 1, wherein said selected deposition process is selected from the group consisting of chemical vapor deposition (CVD), physical vapor phase epitaxy, sublimation processes, and molecular beam epitaxy (MBE) processes.

5   28. The method according to claim 3, wherein the said selected deposition process is chemical vapor deposition (CVD).

     29. The method according to claim 4, wherein the said selected deposition process is molecular beam epitaxy (MBE).

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     30. The method according to claim 12, wherein said selected deposition process is carried out using precursor gases that are silane and a hydrocarbon for the growth silicon carbide.

15   31. The method according to claim 30, wherein said single-crystal substrate material is hexagonal SiC and said selected heteroepitaxial film material is 3C-SiC.

     32. The method according to claim 31, wherein the growth temperature is in the range 1300°C to 2000°C.

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     33. The method according to claim 10, wherein the said selected substrate material is hexagonal SiC, said selected heteroepitaxial film material is 3C-SiC, said selected deposition process is chemical vapor deposition having precursor gases of silane and

propane and having a growth temperature of said selected deposition process being decreased in a ramp manner from a value of approximately 1600°C to a value of approximately 1500°C over a time period of approximately one (1) hour.

5   34.   The method according to claim 15, wherein the said selected boundary shapes are rectangular with areas that range between 1 x 10^{-4}cm^2 and 1 x 10^{-2}cm^2.

35.   The method according to claim 1, wherein said single-crystal substrate material is hexagonal SiC and said heteroepitaxial film material is diamond.

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36.   The method according to claim 36, wherein said single-crystal substrate material is 4H-SiC.

37.   The method according to claim 1, wherein said single-crystal substrate material is

15   hexagonal SiC and said heteroepitaxial film material is a III-N alloy.

38.   The method according to claim 38, wherein said heteroepitaxial film material is a cubic III-N alloy.

20   39.   The method according to claim 38, wherein said heteroepitaxial film material is a hexagonal III-N alloy.

40.   The method according to claim 37, wherein said heteroepitaxial film material is GaN.

41. The method according to claim 37, wherein said heteroepitaxial film material is AlN.

42. The method according to claim 37, wherein said heteroepitaxial film material is AlGaN.

43. The method according to claim 37, wherein said heteroepitaxial film material is InGaN.

44. The method according to claim 1, wherein said single-crystal substrate material is silicon and said heteroepitaxial film material is 3C-SiC.

45. The method according to claim 1, wherein said single-crystal substrate material is SiC and said heteroepitaxial film material is silicon.

46. The method according to claim 1, wherein said single-crystal substrate material is silicon and said heteroepitaxial film material is GaN.

47. The method according to claim 1, wherein said single-crystal substrate material is silicon and said heteroepitaxial film material is AlN.

78

49 48. The method according to claim 1, wherein said single-crystal substrate material is silicon and said heteroepitaxial film material is diamond.

50 49. The method according to claim 1, wherein said single-crystal substrate material is

5   silicon and said heteroepitaxial film material is a silicon germanium alloy.

51 50. The method according to claim 1, wherein said single-crystal substrate material is silicon and said heteroepitaxial film material is a III-V alloy.

51

10 52 51. The method according to claim 50, wherein said single-crystal heteroepitaxial film material is GaAs.

52. The method according to claim 2, wherein a surfactant is used in said selected deposition process of step c) to reduce said produced average rate of nucleation of the

15 said heteroepitaxial film on the said step-free surfaces.